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AIR-TO-AIR COMBAT SKILLS: CONTRIBUTION OF PLATFORM MOTION TO INITIAL TRAINING

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This study was conducted to assess the contribution of six-degrees-of-freedom platform motion to the training effectiveness of the Simulator for Air-to-Air Combat (SAAC) for training initial air-to-air combat skills. A transfer-of-training scheme was used. Two classes of Air Force pilots receiving initial training in the F-4 aircraft were divided into three groups. Two of the groups (eight pilots each) received training in Basic Fighter Maneuvers (BFM) using the SAAC, one group using platform motion and the other group not using platform motion. The remaining group (six pilots) did not receive SAAC training. All three groups followed the same syllabus in the aircraft.

Instructor pilot ratings of student performance on BFM tasks in the simulator and in four aircraft sorties for each student were collected. Analyses of Variance (ANOVAs) of ratings in the simulator were used to assess initial

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differences and learning effects in the simulator. ANOVAs of ratings in the aircraft were used to assess transfer of training effects.

Although learning effects in both simulator and aircraft were noted, the data did not show a transfer of training effect. For the tasks investigated, SAAC trained students did not perform better than those who did not receive SAAC training. Performance differences between the Motion and No-Motion groups were negligible. Potential reasons for this non-effectiveness, and possible simulator and training program modifications for improving this training effectiveness, are discussed.

PREFACE

This effort was conducted by the Flying Training Division of the Air Force Human Resources Laboratory, Williams Air Force Base, Arizona. The research was performed by the Tactical Research Branch at Luke Air Force Base, Arizona. The effort was completed under project 1123, Flying Training Development; task 112312, Tactical Combat Aircrew Research and Development; and work unit 11231208, Platform Motion Requirements for Initial Training of Air-to-Air Combat Skills. Mr. W. M. Dubé assisted with data collection and Mr. William Hopkins assisted with data analysis. The authors would like to thank the personnel of the 311th and 426th Tactical Fighter Training Squadrons for participating in the study as instructers and students. Special thanks are extended to Major William Douglass (4444th Operations Squadron) and Major Michael Tietge (Tactical Air Warfare Center) for their support for the duration of the study. This technical report covers research performed between January and April 1977.

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I. INTRODUCTION

General Background

Until recently, the need for platform motion on aircraft simulation devices was largely accepted on an intuitive basis. It was felt that some degree of motion enhanced the "realism" of the simulation and thus provided more effective training. For the most part, both the Air Force and the commercial airline industry have maintained this posture for some time. Recently, however, this traditional posture has been questioned from both training and cost viewpoints. The essential training question is whether the transfer of training from simulator to aircraft is enhanced by simulator platform motion. Procurement, facility, and operation and maintenance costs vary substantially as a function of the inclusion or exclusion of platform motion. Because of the number of planned Air Force simulator procurements, wise investment strategy dictates that funds available be used for features which can be shown to augment training effectiveness.

Other recent studies by the Air Force Human Resources Laboratory (AFHRL) have addressed various aspects of motion cueing (e.g., Gray & Fuller, 1977a, 1977b). It should be pointed out, however, that none of these earlier studies involved a wide angle visual system nor were the tasks investigated representative of the more complex flying tasks. A number of recent investigations at the Flying Training Division (AFHRL/FT) using the Advanced Simulator for Pilot Training (ASPT) indicated that platform motion did not enhance simulator training effectiveness for some Undergraduate Pilot Training (UPT) tasks (Martin & Waag, 1978a, 1978b; Woodruff, Smith, Fuller, & Weyer, 1976). The Tactical Air Command (TAC) was extremely interested in the implication of these findings in view of their planned simulator procurements. The applicability of UPT research results to the major TAC missions, i.e., air-to-surface weapons delivery (A/S) and air-to-air combat (A/A), was questioned. It was noted that not only are TAC pilots and pilot students more experienced than UPT students but that they also fly higher performance aircraft and perform more complex tasks.

The question at issue is quite complex. It may be postulated that several factors are relevant, i.e., pilot experience, type of task, type of aircraft, capability of training device, and scope of training program. Regarding pilot experience, it may be argued that novice pilots need motion cueing to help them learn to do the assigned task. More experienced pilots may somehow be able to compensate for an absence of such cues and thus may not need simulator platform motion. Alternatively, novice pilots may be so overloaded that they would not use motion cues. More experienced pilots, according to this line of reasoning, may be the ones who benefit most from platform motion cues.

There is another argument that may be used in support of platform motion. Perhaps the value of such motion cueing is its negative aspects rather than its positive ones. In other words, learning transfer to the aircraft is increased because bouncing around the simulator may teach students to ignore motion "cues." This is, in effect, stating that platform motion makes for a "noisy" and thus more realistic learning environment in the simulator. Subjective opinion about the utility of platform motion was (and is) divided with both proponents and opponents being equally vigorous in supporting their position. Therefore, a series of "motion studies" involving TAC pilots and missions was requested.

Planned TAC Motion Studies

Initially, a set of four studies was planned: two addressing platform motion cueing for A/A tasks and two addressing A/S tasks. These included (a) the current A/A study using the simulator for Air-to-Air Combat (SAAC); (b) an A/A study using Northrop Corporation's cantilever beam Large Amplitude Simulator with Wide Angle Visual System (LAS/WAVS); (c) an A/S study using both SAAC and the model board from Weapons System Training Set (WSTS) #18; and (d) an A/S study using AFHRL's Advanced Simulator for Pilot Training (ASPT) at Williams AFB. Both the LAS/WAVS A/A study and the SAAC/WSTS #18 A/S study were cancelled at TAC's request, but the ASPT A/S study was completed (Gray & Fuller, 1977a).

Study Objective

The specific objective of this study was to determine the contribution of six-degrees-of-freedom platform motion to the training effectiveness of the SAAC for initial training of F-4 air-to-air combat skills. This objective was met in two steps: (a) the basic effectiveness of SAAC training was to be established, and (b) the change in effectiveness, if any, due to the addition of platform motion was to be assessed.

II. METHOD

The study was designed to be conducted in the most operationally realistic manner possible. Departures from normal training procedures were kept to a minimum in order to enhance the generality of the results.

Maneuver Selection

In studying the effects of motion cueing on the learning of Air Combat Maneuvering (ACM) skills, theoretically, all air combat maneuvers in which motion cueing is likely to have an effect could be investigated. There are, however, some problems with this concept. First, as maneuvering becomes more advanced, measurement becomes more of a problem. Criteria are less well defined and different maneuvering combinations are used to achieve the same end. Second, training device capability becomes a problem. While a significant portion of F-4 air-to-air training emphasizes two vs. one maneuvering, the SAAC can only present a single aircraft image in the visual scene in each cockpit. The SAAC does have the capability to use the spot it generates as a "sun" image for a wingman "image" in two vs. one maneuvering. However, during the SAAC Follow-On Operational Test and Evaluation (FOT&E) (TAC Project 75A-04OU), this arrangement was found to be very unsatisfactory, particularly for students experiencing two vs. one maneuvering for the first time. The third, and probably most important, problem is that the current understanding of how motion cues are perceived by pilots is not yet sufficient to say motion cues are important in maneuver A and not important in maneuver B.

Consideration of the above concepts led to the selection of the Basic Fighter Maneuvers (BFM) phase of training for the transfer-of-training investigation. During the early part of this phase, pilot students are taught the classical maneuvers used in ACM, i.e., Immelmann Attack, Barrel Roll Attack, High Yo-Yo, etc. Performance measurement in this context is likely to be more precise than in later stages of ACM training. The tasks are quite well defined and are practiced from fairly standard situations, and the conditions of training for different students are more similar during this stage than for later stages of training. The set of maneuvers investigated is listed in Table 1. Both "Tactical Formation" and "Set up on Perch" are not part of the BFM but are flying tasks normally practiced during the BFM training phase. All of these tasks involve control input behavior; that is, stick, throttle, and rudder movement by pilots. During BFM training, students are also rated on a set of tasks which are more cognitive or less control input oriented than are the classic BFM tasks. This set of BFM "skills" (Table 2) was included in the study because it was thought that they may be enhanced by simulator training. These skills are practiced during the execution of BFM tasks.

Table 1. **BFM Tasks (Set 1 Variables)**

Acceleration Maneuver
High Yo-Yo
Quarter Plane
Barrel Roll Attack
Immelmann Attack
Lag Roll
Separation
Tactical Formation
Set up on Perch
Defensive Maneuvers

Table 2. **BFM Skills (Set 2 Variables)**

Descriptive Commentary
Range Estimation
Target Acquisition
Kept Bogey in Sight
Weapons Parameters Recognition
Switchology
Preparation
Attitude
Judgment

Subjects

The pilot students assigned to the F-4 B-course classes 77-EBL and 77-FBL at Luke AFB served as subjects for this study. There were 22 students, 11 assigned to the 311 Tactical Fighter Training Squadron (TFTS) and 11 assigned to the 426 TFTS. The 11 students in each class were divided into three groups as shown in Table 3:

Table 3. **Subject Grouping**

Group	Class 77 EBL	Class 77 FBL	Total
Motion	4	4	8
No-Motion	4	4	8
No-SAAC	3	3	6
			22

Groups were matched by first ranking the pilots in each class based on their performance during UPT, Fighter Lead-In Training, and progress to date at Luke AFB. Squadron, Instructional System Development (ISD), and AFHRL personnel participated in making the rankings. Group assignment was then made using a counterbalancing procedure. Two students in each class had previous experience, as F-4 Weapon System Officer, and these were assigned to the Motion and No-Motion groups prior to assignment of the remainder of the students.

Instructors

Instruction in both the SAAC and the aircraft was given by the regular squadron Instructor Pilots (IPs). Normal procedures for pairing students and instructors were followed for all sorties except the SAAC checkride (SAAC 7). All SAAC 7 missions were given by one of two IPs (one from TAWC/OLAH and one from the TAC ISD squadron) with each IP assigned to rate half of the pilot students in the Motion and No-Motion groups, respectively. Most of the instructor pilots had several hours of experience in the SAAC, and many had used it to train students during the SAAC FOT&E; others had participated in continuation training sorties in the SAAC. The SAAC-experienced instructors were given a brief refresher sortie in which the modified freeze feature and setups available were demonstrated. Those instructors who had not flown previously were given two familiarization sorties by either TAWC/OLAH or ISD personnel. All were encouraged to use the freeze, reset, and other instructional capabilities of the SAAC.

Apparatus

The apparatus used in the study consisted of the SAAC and the F-4C aircraft. A detailed description of the SAAC is contained in the FOT&E reports (TAC Project 75A-04OU), and only a brief description will be presented here.

The SAAC is comprised of two F-4 cockpits, mounted on synergistic six-degrees-of-freedom motion systems. Each cockpit is enclosed by a matrix of eight pentagonal cathode ray tube windows providing a 296- by 150-degree field of view. An electronic synthetic terrain generator and a camera model aircraft image generator provide the visual display. A g-suit and g-seat system augments the buffet and vibration cues derived from the motion system. Missile and gunfire trajectories are computed through a scoring system that displays a simulated "kill" during engagements.

Maintenance on the SAAC is accomplished via contract with the Simulation Products Division of Singer Company. Prior to the conduct of this study, Singer reported that the motion system on SAAC was adjusted to specifications and was performing properly. During this study, normal maintenance procedures were followed. A problem with one of the legs was noted approximately 2 weeks after completion of the data collection. Examination revealed that failure of a component in one of the legs resulted in a small degree of cross-coupling in two of the degrees of freedom, but it was not possible to determine when this failure had occurred.

Two modifications to the system were requested well prior to the conduct of this study. During the SAAC FOT&E, it was found that instructors were reluctant to use the SAAC instructional features other than reset. Due to the low reliability, or operating inconvenience of these features, AFHRL personnel suggested that greater use of the problem freeze and record/playback features, in particular, might have a strong potential for increasing student learning. The problem freeze allows the instructor to stop the two cockpits at any point. The capability to stop and give the student feedback about what has just occurred can be a powerful instructional tool. Prior to the current study, the use of the freeze feature in SAAC required the instructor, who was normally in one cockpit, to request the console operator to initiate a freeze. Even when the operator responded immediately, the delay due to the time required for communication often resulted in the desired situation being lost. Prior to the current study, the nose wheel steering switch on the control stick was wired to become a freeze control. A freeze could then be initiated or released from either cockpit.

Similarly, the record/playback feature had not worked reliably on SAAC. In addition, the series of operations required of the console operator to use the feature were complex enough to result in frequent errors. As a result, record/playback was rarely used. In light of this, modifications were requested to improve system reliability and ease of operation and to provide a "visual slaving" capability in the playback mode. This would allow both cockpits (i.e., instructor and student) to view a just recorded engagement from either the student's or the instructor's viewpoint. It was thought that this capability could be a valuable feedback tool, particularly for students who are being taught ACM fundamentals for the first time.

Technological problems resulted in these modifications not being completed in time to support the study.

Training Syllabus

The normal training syllabus was followed except for modifications necessary to support the study. These exceptions involved moving forward some of the relevant ACM academics, adding seven SAAC simulator sorties for the Motion and No-Motion groups, and adding an additional BFM sortie in the aircraft. The SAAC portion of the syllabus consisted of two familiarization sorties, four training soritics, and a checkride sortie. The additional aircraft BFM sortie was inserted to increase the number of practice trials for those maneuvers under investigation. The relevant portions of the training syllabus are shown at Appendix A.

A "blocked" training model was followed in building the syllabus, in that all SAAC training was scheduled to be completed prior to beginning the corresponding aircraft sorties. This mode of training was chosen to more effectively demonstrate any training effects of the SAAC and to facilitate scheduling.

The number of SAAC sorties included was based on experience with the SAAC FOT&E. Two short orientation sorties rather than a single longer one was thought to be more appropriate, particularly for those few students who may experience a first time queasiness in an advanced simulator such as SAAC. It was also noted during the SAAC FOT&E that four to five BFM training sorties tended to bring students to a plateau where they were anxious to try BFM in the aircraft and were just beginning to lose motivation for repeatedly performing BFM tasks in the SAAC.

Instruction in the SAAC

During the simulator training, an IP flew one cockpit and the student flew the other. All students flew the same cockpit, displaying an F-4 aircraft image in its visual scene. It was decided that such a mode of operation was the best available option for this study. Instructing the students from the console was not attempted because of the limited visual feedback available to the instructor. While the current instructional capabilities may have been enhanced by having two IPs present, one at the console and the other in one cockpit, manning levels available at the time were not sufficient to support this option. The console was operated by AFHRL personnel. All instructional decisions were made by the IP. When asked, AFHRL research personnel provided feedback concerning such information as range and aspect angle from displays on the console.

System Configuration

Both the g-seat and the g-suit were used by the instructors and students for all simulator training sessions. The use of platform motion for subjects was determined by group assignment. The Motion group students flew SAAC with platform motion for all training; the No-Motion group students flew SAAC without platform motion for all training. The instructors had the option of flying SAAC with or without platform motion, but most elected not to use it.

Grading Scale

TAC nominally uses a 5-point grading scale (0-4). The definitions of these grades as printed on the grade sheet are given in Appendix B. In practice, IPs report that the large majority of grades actually given are 1's and 2's. A few grades of 0 and 3 are given and grades of 4, although used very rarely for items like "Attitude" or "Preparation," are essentially nonexistent. It was thought that the normal grading system was inadequate for the present study because, for most maneuvering, it was essentially a 2-point scale (1 & 2). In order to provide more precision in measuring the effects of simulator training and differences due to motion, a more precise grading scale was necessary. A variety of scales was considered in discussions with ISD and instructor personnel. It was decided that the current scale could be expanded to increase precision by adding "plus" and "minus" categories. Such a procedure did not require extensive learning of new criteria or anchor points by the instructors.

Grading Instructions

Squadron personnel were briefed on the special grading procedures to be used for the study, and a grading guide was left at the squadron for use during the four specially graded aircraft sorties. Instructors were asked to rate each individual maneuver on a special grade card both in the simulator and in the aircraft. These grades were in addition to the normal method of a single grade for each type of maneuver. Thus, if a student did three acceleration maneuvers on a given day, four ratings for that maneuver were made: a rating for each of the three "trials" and an overall or "daily" grade for that task.

Data Collected

The primary data consisted of the performance ratings made during the four aircraft sorties, BFM

4 through BFM 6B. During SAAC training, rating data were collected for each of the maneuvers listed in Table 1 and for each of the skills listed in Table 2. In addition, questionnaire data were collected from both students and instructors. The questions asked were of a non-directive nature (Appendix C). It should be noted that most of the instructors involved had recently completed very detailed questionnaires during the SAAC FOT&E, the results of which are to be described in a Final Report by TAC (TAC Project 75A-04OU).

III. DATA ANALYSES AND RESULTS

For the purposes of analysis, the performance ratings made by the IPs were first rescaled according to Table 4. Several one-way analyses of variance (ANOVAs) (Evanson, 1975) were performed to assess the significance of the differences in performance among the three groups. It was decided that the normal $p < .05$ and $p < .01$ criteria for significance were too strict for the current study; therefore, a more liberal $p < .10$ was used. With this criterion a difference among groups is termed significant when it may be expected to occur by chance no more than one time in ten. The choice of this liberal criterion meant that there was more of a chance that increased performance increments due to motion were labelled significant.

Table 4. **Transformation Used Prior to Analyses**

Rating Given	Rating Used for Analysis
3+	9
3	8
3–	7
2+	6
2	5
2–	4
1+	3
1	2
1–	1
0	0

Each analysis was accomplished to answer a specific question. These questions are addressed separately in the following sections with both the analysis performed and the results obtained described. The simulator data are presented before aircraft data. Table 5 lists the mean ratings given for each group at different points in training; each

Table 5. **Mean Performance Ratings for BFM Maneuvers**

Training Phase	Group: No-SAAC	No-Motion	Motion
Initial Simulator	–	3.94	3.93
Final Simulator	–	4.85	5.45
Initial Aircraft	4.03	3.73	3.64
Final Aircraft	4.89	4.56	4.47
Overall Aircraft	4.44	4.20	4.13

entry is averaged across subjects and the BFM maneuvers listed in Table 1. Table 6 similarly lists the mean ratings for each group averaged across subjects and the BFM skills listed in Table 2.

Table 6. **Mean Performance Ratings for BFM Skills**

Training Phase	Group: No-SAAC	No-Motion	Motion
Initial Simulator	–	5.65	5.02
Final Simulator	–	5.58	6.49
Initial Aircraft	5.17	4.79	4.96
Final Aircraft	5.22	5.24	5.19
Overall Aircraft	4.98	5.12	5.12

Initial Group Equality

The first question of interest concerns the relative performance of the Motion and No-Motion groups at the beginning of simulator training. It was stated earlier that groups were matched to the greatest possible extent. If the matching was successful, consistent differences in performance between the Motion and No-Motion groups would not be expected. To address this issue, the first daily ratings for each maneuver and skill were analyzed. These ratings were generally from simulator sorties 3 or 4, sorties 1 and 2 being dedicated to simulator orientation. Two kinds of analyses were made. In one type of analysis, performance on each maneuver was considered in a separate ANOVA. For purposes of discussion, this type of analysis will be termed a "secondary" analysis. Using this method, none of the differences was significant for any of the Set 1 or Set 2 Variables. The mean ratings for each group and task are shown in Table D1 in Appendix D. Also presented is the significance probability from the ANOVA for each maneuver. It should be noted that when large numbers of ANOVAs are performed, as was done in the secondary analysis, some "significant" differences are likely to be due to chance (i.e. approximately one in ten for the chosen criterion).

However, if a large number of significant differences are found, it may be assumed with confidence that real differences do exist.

Since considering each maneuver or skill separately does not give a picture of overall effects, another type of analysis was conducted. This analysis grouped together the BFM tasks (Set 1 Variables) as a set of repeated measures. The BFM skills were similarly grouped together as a second set of repeated measures. This was done under the assumption that, although the differences for the particular maneuvers or skills may be small, they may be important if one group consistently performs better than the other group at most or all tasks. In the following paragraphs, this type of analysis will be referred to as a "primary" analysis because it considers tasks collectively. For Set 1 Variables, the difference between the two groups was not significant, but for Set 2 Variables, the No-Motion group had significantly higher ratings. The mean performance ratings for both groups are shown in the "Initial Simulator" row in Tables 5 and 6. The means and significance levels from the primary analysis are also included in Table D1.

Learning in the Simulator

The second question of interest is whether students learned in the simulator. If learning had occurred, higher ratings during the last sortie would be expected. To address this question, the first daily rating for each variable for each group was compared to ratings given during the last simulator sortie, SAAC 7. A primary analysis confirmed these expectations. Highly significant differences were noted for both sets of variables for the Motion group and for the Set 1 Variables for the No-Motion group. Differences on Set 2 Variables were not significant for the No-Motion group. In fact, the mean initial and final performance ratings on Set 2 Variables were almost identical.

When first vs. last ratings were compared for each task through a secondary analysis, differences were consistently in the expected direction for all but the No-Motion Set 2 Variables. Significant differences were also found in the Set 1 Variables. The significant probabilities for these first vs. last ANOVAs are listed in Table D6.

Final Simulator Standings

The remaining question of interest concerns the status of the two groups as they completed simulator training. A primary analysis compared the performance of both groups for each set of variables. For both sets of variables, the ratings received by the Motion group were significantly better than those of the No-Motion group. There was, however, a problem. It was intended that each of the two IPs who conducted the SAAC 7 checkrides should evaluate four students from each group. A scheduling error resulted in one IP evaluating five No-Motion and three Motion students and the other IP evaluating three No-Motion and five Motion students. The result of this partial confounding of group and IP evaluator is that the higher ratings of the motion group may be due to IP bias, to motion, or to both. The means and significance levels for these data are shown in Table D2.

Analyses of Aircraft Data

The data were analyzed to measure transfer of training to the aircraft. The analyses were similar to those used for the simulator data. In addition to the data analyses of initial performance levels, final performance levels, and learning effects, an overall category was included which averaged together all daily ratings for each task in the aircraft for each subject. The same types of analyses were conducted on both trial and daily rating data for Set 1 Variables. Since the results from the analysis of trial data are very similar to those obtained with the daily rating data, only the latter are presented. As with the simulator data, the means and significance probabilities from the ANOVAs are presented in Appendix D. The means from the primary analysis are also shown in Tables 5 and 6.

Initial Aircraft Data

There are several hypotheses about how and where the effectiveness of simulator trained groups should show up. The most common of these is that simulator trained groups should exhibit a higher "initial" skill level when the aircraft phase of training is begun. When simulator training is "blocked," that, completed prior to aircraft training rather than interspersed with it, this expectation seems quite reasonable. A primary analysis of the first daily ratings for each task resulted in differences among the three groups that were not significant. However, and somewhat surprisingly, the mean rating for the No-SAAC group was slightly higher than those for the two SAAC trained groups, which differed only slightly.

When the data for the Motion and No-Motion groups are combined, the analysis becomes a comparison of SAAC trained vs. No-SAAC trained subjects. Even though such a test is more powerful due to increased sample size, the SAAC vs. No-SAAC difference does not reach significance for either set of variables.

When the initial aircraft data for the three groups are analyzed for each task separately, a secondary analysis, two of the differences were significant but were not in a consistent direction and are no more than would be expected by chance.

Learning in the Aircraft

The next analysis was concerned with whether the ratings showed that learning occurred in the aircraft. It is not obvious that ratings necessarily reflect the degree of learning taking place. Current economics do not allow the same maneuver to be continually practiced under the same conditions. As soon as a student attains some degree of proficiency, the conditions of practice for a particular maneuver may change just enough that the student remains challenged but still experiences some success. This is particularly true in the air combat phases of training. For example, a student's first attempts at Acceleration Maneuvers and Hi Yo-Yos are likely to occur in very standardized situations. However, the last trials occurring in the sorties under study may be in conditions which more nearly resemble free engagement. The effect of these changing conditions on IP grading criteria and resultant ratings are unknown. However, it is reasonable to assume that these same unknown factors affect all three groups.

The first daily rating vs. last daily rating comparison was made for each group separately for both Set 1 and Set 2 Variables. The results of the primary analyses for all three groups were the same. On Set 1 Variables, the last daily ratings were significantly higher than the early ratings. On Set 2 Variables, the differences were in the expected direction but did not reach significance. When the data from all three groups are combined, the difference reaches significance ($p=.08$).

As with the simulator data, a secondary analysis resulted in more significant differences for Set 1 Variables. The significance probabilities from these ANOVAs are also listed in Table D6.

Final Aircraft Data

In a previous section, the expectation that simulator trained groups may enter the aircraft phase of training with an advantage was discussed and basically rejected. The groups were not found to be significantly different. Several hypotheses may be generated concerning the comparative state of the groups at the end of the period under investigation. There may be no differences, which implies either that they never existed or that any that did exist have been obscured. SAAC trained groups may rate higher if the basic simulator effectiveness shows up later in training rather than initially. This result can occur if the SAAC trained students have acquired what is termed a better "situation awareness" which could exhibit itself after an initial settling period. On the other hand, if the SAAC trained students have picked up some bad habits, they may not perform as well.

A primary analysis of the last daily ratings indicated a significant difference for the Set 1 Variables collectively. Surprisingly, the difference was in favor of the No-SAAC group. Differences between the two SAAC trained groups appeared to be negligible. The differences for Set 2 Variables were not significant.

Overall Aircraft Data

For this analysis, all of the daily rating data were used. For all variables, the ratings were averaged together for each task and subject. For the Set 1 Variables, the differences again were in favor of the No-SAAC group and approach significance ($p=.12$). For Set 2 Variables, the difference between groups appeared to be negligible. On the secondary analysis the only significant effect was for the acceleration maneuver. The No-SAAC group again scored highest.

Questionnaire Data

Since the questionnaire data were not quantitative, they were not submitted to a statistical analysis. Students responded that SAAC training helped them to acquire an initial advantage in being better able to picture BFM maneuvers. There were mixed comments as to whether the SAAC training actually helped them to perform the maneuvers any better. Student opinion with regard to platform motion generally indicated that they thought it did not or would do nothing to help them. Those students that flew with platform motion often stated that after the first two or three sorties they did not pay any attention to it.

Instructor opinions were generally in agreement in that they perceived no differences between the SAAC and No-SAAC trained students insofar as performance in the aircraft was concerned. A small number of the IPs thought that SAAC trained students did have a slight initial advantage in performance. It was thought that this advantage disappeared after one or two sorties. Several of the IPs also agreed with the students that SAAC gave the students a good initial "picture" of BFM tasks. IP comments about motion were mixed, with those not in favor of motion making the stronger statements. As mentioned previously, most of the IPs when given the choice during the training of students opted not to use platform motion for themselves.

The Tactical Air Command SAAC FOT&E final report and the Simulator Comparative Evaluation report contain a more comprehensive discussion of questionnaire data about the SAAC.

IV. DISCUSSION AND RECOMMENDATIONS

The objective of this study was to determine the contribution of six-degrees-of-freedom platform motion to the training effectiveness of the SAAC for initial training in A/A tasks. There were two primary parts to this objective: (a) the basic training effectiveness of the SAAC and (b) the increment in effectiveness when platform motion is used. The current data did not reflect any noticeable increment of effectiveness due to platform motion. There were no consistent transfer-of-training differences between the Motion and No-Motion groups. This result, however, must be interpreted in the context of a lack of demonstrated training effectiveness of the SAAC itself. The data indicated that SAAC training did not seem to increase instructor ratings of performance in the aircraft. If anything, there is some indication that the students who did not receive SAAC training performed better in the aircraft. This basic non-effectiveness will be discussed at length prior to returning to the question of motion. The reader should keep in mind the integral relationship of training program and training device. Training effectiveness is a function of both of these. Even though significant training effectiveness was not demonstrated under the conditions and restrictions of the current study, this does not mean that all SAAC training will be noneffective. It only means that the right training program and training device capability combination was not demonstrated in this study.

Relationship to Previous Results

To date, there have been only two studies that are closely related to the current study. The first of these (Payne, Hirsch, & Temple, 1976) involved the training of Navy F-4 pilots on Northrop's air combat simulator. That study was a very structured training experiment involving extensive experimental control including fixed IP and student pairings. In addition, up to 12 performance ratings were made for each trial of each maneuver. The current study, in an attempt to be as operationally oriented as possible, imposed a minimum of departures from normal training procedures. The Northrop study found a consistent positive transfer-of-training effect. Simulator trained students for the Northrop study performed better in the aircraft than those students who did not receive the simulator training. Although transfer of training was noted in a variety of ways, differences were not large enough to be significant except for the Rolling Scissors maneuver. No across maneuvers or summary analyses were reported.

The other study which is most relevant was the Phase II or student training phase of the SAAC FOT&E. A comparison of instructor ratings from BFM training yielded results similar to those from the Northrop study, a very small positive effect. Differences were not significant in a statistical sense.

The most closely related study done by AFHRL involved the training of UPT students on the ASPT in aerobatic maneuvers (Martin & Waag, 1978b). That study also did not find large transfer of training effects. The only maneuver which showed a significant transfer of training effect was the Barrel Roll.

The notable exception to the small effects noted above is the A/S motion study (Gray & Fuller, 1977a, 1977b). This study found a very significant transfer of training effect. The addition of platform motion, however, did not increase this transfer.

In summary, except for the A/S motion study, the results of the studies to date that are most closely related to the current study are similar in that the measurable effects of simulator training for ACM related tasks tend to be small.

The Measurement Problem

There are several possible explanations for the lack of a demonstrable positive transfer of training. One problem is that of performance measurement. Performance measurement in the aerial combat arena is a difficult task. Standards of performance are less well defined than for other flying tasks. For the current study, it was assumed that instructor ratings on the expanded scale used were sufficiently sensitive and reliable. Even though this was the chosen option, this assumption may be questioned.

Another possible problem with measurement is more conceptual. If what a student learns in a training device like SAAC is an overall "situation awareness" as some instructors report, then how this knowledge would be exhibited is not precisely clear. It was expected that this might show up in the ratings on the Set 2 Variables since those skills are more cognitive in nature than the Set 1 Variables. However, ratings on these variables were less sensitive to training effects than ratings on Set 1 Variables.

The remaining point about performance measurement concerns training program modifications. Inclusion of training on a device like the SAAC is not routinely justifiable without measurable transfer of training. This reservation, of course, should not prevent experimental manipulations in attempts to find improved training procedures and measurement tools.

Negative Training

It has long been a well established fact that prior training in a simulator improves performance and/or learning in the aircraft. The degree of this facilitation is a complex function of the task to be performed, training device capability, instructor competence, and content and sequence of instruction within the training program. While operational personnel have often expressed a concern that negative training may occur, particularly when the simulator vs. aircraft procedures or handling characteristics are quite different, no such negative effects have been reported to date. For this reason, the advantage of the No-SAAC group at the end of the training period under consideration is worthy of note. This performance difference may, of course, be due to a sampling bias. In spite of the matching procedures employed, the better pilots may have ended up in the No-SAAC group. Another potential explanation appeals to the motivation of the individuals involved. In one of the squadrons, the No-SAAC students were reported to have established a rapport and a "we're good enough not to need the SAAC" attitude or team spirit. A third possibility is that of instructor bias. The expectations of instructors may have been different for SAAC trained and No-SAAC trained students. While these possibilities cannot be discounted, it is thought they should not be relied on either. Therefore, the SAAC training program was examined to look for other potential explanations. Two particular problems were noted.

One problem concerns the scheduling of SAAC training. For those students who received it, SAAC training was an additional activity. It is possible that SAAC training interfered with other training merely because it took time and required attention at the critical time when students were just learning basic aircraft control during transition and formation training. The SAAC trained students may have fallen increasingly farther behind their classmates. While the difference from the No-SAAC group was small at the beginning of aircraft training, it became large enough to become significant at the end of the period under consideration. Although this hypothesis is consistent with the observed data, there is no way to verify that it actually occurred. The implication for training program developers and researchers is that too many activities should not be competing for a student's time and attention.

The second problem concerned the way in which the SAAC training was actually conducted. It is very possible that the amount of feedback which the student received was not adequate for his current stage of training. In this study, the IP instructed from the target aircraft. While this was the best option available in SAAC at the time, this position is certainly not optimal. It may not have allowed the IP to perceive, and correct, the development of some minor "bad habits" which later interfered with the student's progress. Note that the term "minor" is used. It is expected that major problems (a) would have been detectable by the IP from his position in the target aircraft in SAAC and (b) may have resulted in obviously poorer performance in the early aircraft data. The latter was not reflected in the ratings or mentioned by instructors on the questionnaires.

A similar problem was the difficulty of adequately demonstrating a maneuver in the SAAC. Since the IP and the student were not able to see the same image simultaneously, it was hard to talk the student through a demonstration. It was because of these difficulties that the "visual slaving" capability of the record/playback system was requested earlier.

Experience, Instructional Features, and Effectiveness

In the previous section it was speculated that the training effectiveness of the SAAC for initial fighter training may be hampered by preventing adequate feedback by instructors. This need for feedback is likely to be greatest when students are initially exposed to the fundamentals of air combat. This was precisely the phase of training with which the current study dealt. In contrast, consider the situation with the more experienced pilot. He is much less likely to require the same kind of feedback from his instructor. He has enough knowledge about air combat maneuvering that he can monitor his own performance. He is likely to have a sufficient concept of the geometry of an engagement that postmission discussion during debriefing may provide adequate feedback. The logic above may explain one of the paradoxes in the SAAC FOT&E results. The majority of instructors felt that SAAC provided effective training to them (the instructors) but was of doubtful value for training students. At the time, this was perceived as a bias against simulation, but perhaps the feedback problem is a more plausible explanation.

The effectiveness of SAAC for experienced pilots was supported by questionnaire data from the Tactical Fighter Weapons Center (TFWC) TAC ACES II project. A similar program being conducted at Vought Corporation in Dallas, Texas, also reported the effectiveness of air combat simulation for experienced pilots (TAC Project 74T-912F).

Both the Vought and the Northrop air combat simulators use a "jump seat" arrangement where the instructor sits to the side and slightly behind the student. Both of these devices also have a record/playback capability. It is felt that for initial fighter training, these capabilities would provide a better training potential than the SAAC arrangement as existed at the time of this study. The visual slaving previously discussed plus the capability of maneuvering against a pre-recorded target, freeing the IP to monitor the student, are seen as the two most promising enhancements which may be made to SAAC.

Simulation Training Procedures

Before returning to the motion question, a few additional observations about training procedures will be presented. These comments relate to the use of simulator unique features. While strong credit must be given to the instructors, who adapted fairly well to the requirement to instruct using SAAC, it became obvious that they were reluctant to use SAAC much differently than they might employ an aircraft, that is, they tended to ignore many of the unique instructional features of SAAC. For example, although the reset feature was used extensively at the completion of a maneuver, rarely was it used to terminate a situation close to the point in time that an error was committed. Error situations were usually allowed to continue and resulted in the compounding or errors. In an aircraft, this compounding of errors would not often happen because it would waste time, the instructor in the rear cockpit would probably coach the student out of error situations early, and it would affect the safety of flight. While it is acknowledged that students must be allowed to see the results of their mistakes and that a simulator such as SAAC is probably a good place to do this, there are times when multiple restarts to shape initial behaviors also may be effective. Similarly, the freeze feature was rarely used. Rather than interrupting an engagement to give immediate feedback, instructors preferred to continue and run another trial. It would seem that segmenting a maneuver into parts and discussing each briefly may sometimes be more effective. The reluctance to use other instructional features on SAAC was felt to be justified. For instance, the use of record/playback would not be expected to aid students in initial experiences with BFM until the feature, including a visual slaving capability, is reliable and easy to use.

Other issues related to simulation training procedures and policy are discussed in two recent HumRRO reports (Caro 1977b, 1977c). Included are issues related to simulator design, training program design, instructor training, user attitudes, and administrative policies.

Platform Motion for Air Combat Simulation

The results of the current experiment leave the question of the need for platform motion for training A/A tasks unanswered. Recommendations from other reports do not support the procurement of platform motion for fighter training devices (TFWC TAC ACES II; Rivers & Van Arsdall, 1977). It is recommended, however, that research and development to optimize platform motion drive algorithms continue on devices currently in the inventory. More information is also needed on how motion cues are perceived and used. With regard to this, the recently articulated distinction between "maneuver" motion cues and "disturbance" motion cues (Caro, 1977a) may be important. Maneuver motion results from pilot initiated (control input) changes in the aircraft position. Disturbance motion arises outside this control loop from turbulence or from airframe equipment or engine component failure.

For the continuation training of experienced pilots, the platform motion question is even more difficult. It is anticipated that it would be very difficult to achieve measureable changes in performance. The subjective opinions of operational pilots may be the only data currently available on which to base these decisions.

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TRAINING SCHEDULE

Training Day	
21 to 24	Initial ACM Academics
23 to 43	SAAC Training Sorties 1 to 7
44 to 49	BFM Sorties 4 to 6B

SAAC Training

		Crew	Time	Configuration
SAAC 1	Orientation	IP, AC	.5	D-33

Sound-on-slide briefing (emphasize safety), cockpit checkout (emphasize egress), transition maneuvers (low AOA roll, lazy eight, loop), advanced handling (acceleration maneuver, break turn, pitchback, sliceback), out-of-control recovery, spin recovery, egress.

SAAC-2	Orientation	IP, AC	.5	D-33

Transition maneuvers (Immelmann, cloverleaf), advanced handling (sliceback, pitchback), tracking exercise, fighting wing, free engagement.

SAAC-3	BFM Training	IP, AC	.7	D-55

Tactical formation (AC flies #3 position), set up on perch, estimate range, select and arm AIM-9, acceleration maneuver, high yo-yo, launch AIM-9, quarter plane maneuver, lag roll, separation maneuver, fighting wing, free engagement.

SAAC-4	BFM Training	IP, AC	.7	D-55

Set up on perch, auto-acquisition lock on, acceleration maneuver, high yo-yo, quarter plane maneuver, barrel roll maneuver, Immelmann turn, counter low yo-yo, counter high yo-yo (executed late), fighting wing, free engagement.

SAAC-5	BFM Training	IP, AC	1.0	D-33

Set up on perch, acceleration maneuver, high yo-yo, select, arm and fire gun, quarter plane maneuver, barrel roll maneuver, Immelmann turn, counter high yo-yo (executed early, executed properly), fighting wing, free engagement.

SAAC-6	BFM Training	IP, AC	1.0	D-66

Tactical formation, tactical intercept, tune and arm AIM-7, launch AIM-7, stern conversion, launch AIM-9, high yo-yo, barrel roll, Immelmann turn, counter barrel roll attack, break turn, free engagement.

SAAC-7	BFM Evaluation	IP, AC	1.0	D-66

Tactical formation, set up on perch, acceleration maneuver, high yo-yo, barrel roll maneuver, Immelmann turn, defensive counters, launch AIM-9, launch AIM-7, fire gun, free engagement.

Aircraft Sorties

	Crew	Time	Configuration
BFM 4	AC/IP, AC/IP	1.3	D-33

Formation takeoff, tactical formation, auto-acquisition lock-on, high yo-yo, acceleration maneuver, quarter plane maneuver, separation maneuver, fighting wing.

BFM 5	AC/IP, AC/IP	1.3	D-33

Formation takeoff, tactical formation, tracking exercise, high yo-yo, barrel roll maneuver, Immelmann turn, quarter plane maneuver, separation maneuver, fighting wing.

BFM 6A	AC/IP, AC/PI	1.3	D-33

Formation takeoff, tactical formation, barrel roll maneuver, Immelmann turn, quarter plane maneuver, defensive counters, separation maneuver, fighting wing.

BFM 6B	AC/IP, AC/IP	1.3	D-33

Formation takeoff, tactical formation, high yo-yo, quarter plane maneuver, barrel roll maneuver, Immelmann turn, defensive counters, separation maneuver.

Configuration Code

Fuel Configuration:
A – Full internal
D – Full internal/2 x 370 gallon tanks full
Munitions Configuration:
33 – Clean, inboard pylons, internal gun.
55 – AIM-9, 4 ea., internal gun.
66 – AIM-7, 4 ea., AIM-9, 4 ea., internal gun.

APPENDIX B: GRADING CRITERIA

Grade	Definition
Unknown	Performance not observed or the element was not performed.
0	Performance indicates a lack of ability or knowledge.
1–	
1	Performance is safe but indicates limited proficiency. Makes errors of commission or omission.
1+	
2–	
2	Performance is essentially correct. Recognizes and corrects errors.
2+	
3–	
3	Performance is correct, efficient, skillful, and without hesitation.
3+	
4–	
4	Performance reflects an unusually high degree of ability.

APPENDIX C: QUESTIONNAIRES

Instructions: (Used for Both IPs and Students)

In order to amplify as much data as possible concerning the use of platform motion, please answer the following in as much detail as you feel is warranted and comment on other areas as appropriate. Thank you.

IP Questionnaire:

1. How did the SAAC training affect student performance in the aircraft on BFM?

2. In what manner and to what extent did the platform motion contribute to student proficiency in the aircraft on BFM?

Student Questionnaire:

1. How did the SAAC training (or lack thereof, if you were a non-SAAC student) affect your performance in the aircraft on BFM?

2. Please give specific comments on the use of the motion platform.

APPENDIX D: DATA TABLES

Table D1. **Mean Initial Rating in Simulator and Significance Probability**

Maneuver/Skill	Group: No-Motion	Motion	Significance Probability
Acceleration Maneuver	4.50	4.63	.84
High Yo-Yo	3.88	3.38	.45
Quarter Plane	3.00	3.50	.53
Barrel Roll Attack	3.88	3.00	.23
Immelmann Attack	3.86	3.38	.56
Lag Roll	3.75	2.86	.36
Separation	4.25	5.25	.28
Tactical Formation	4.38	4.75	.59
Set up on Perch	3.63	4 13	.55
Defensive Maneuvers	4.25	4.25	1.00
Descriptive Commentary	4.00	3.75	.77
Range Estimation	4.38	3.38	.27
Target Acquisition	6.14	5 29	.28
Kept Bogey in Sight	5.50	4.67	.40
Weapons Parameters Recognition	5.00	4.83	.79
Switchology	5.40	4.50	.24
Preparation	6.29	6.14	.86
Attitude	7.71	7.29	.45
Judgment	5.86	4.86	.27
Set 1 Maneuvers	3.94	3.92	.96
Set 2 Skills	5.65	5.02	.05*

*Significant at $p < .10$.

Table D2. **Mean Final Ratings in Simulator and Significance Probability**

Maneuver/Skill	Group: No-Motion	Motion	Significance Probability
Acceleration Maneuver	5.13	6.00	.09*
High Yo-Yo	4.00	5.38	.21
Quarter Plane	4.50	6.13	.04*
Barrel Roll Attack	4.75	5.75	.21
Immelmann Attack	5.00	5.38	.62
Lag Roll	+	+	+
Separation	5.25	5.88	.51
Tactical Formation	6.00	5.88	.87
Set up on Perch	3.63	3.38	.81
Defensive Maneuvers	5.38	5.50	.82
Descriptive Commentary	6.25	7.38	.16
Range Estimation	5.20	5.50	.63
Target Acquisition	5.00	6.33	.53
Kept Bogey in Sight	+	+	+
Weapons Paremeters Recognition	3.75	6.00	.15
Switchology	4.25	5.00	.44
Preparation	6.17	6.57	.62
Attitude	7.50	7.57	.92
Judgment	5.00	5.50	.34
Set 1 Maneuvers	4.85	5.45	.03*
Set 2 Skills	5.58	6.49	.01*

*Significant at $p < .10$.
+Insufficient data.

Table D3. **Mean Initial Ratings in Aircraft and Significance Probability**

Maneuver/Skill	Group: No-SAAC	No-Motion	Motion	Significance Probability
Acceleration Maneuver	4.67	4.00	4.13	.51
High Yo-Yo	4.33	3.13	3.88	.26
Quarter Plane	3.33	3.13	3.00	.92
Barrel Roll Attack	3.67	3.75	3.00	.57
Immelmann Attack	3.83	2.88	2.75	.38
Lag Roll	4.17	3.86	3.88	.93
Separation	3.33	4.00	3.13	.72
Tactical Formation	4.17	3.75	3.88	.80
Set up on Perch	4.33	4.63	4.00	.77
Defensive Maneuvers	4.50	4.25	4.75	.72
Descriptive Commentary	4.67	5.13	3.75	.10*
Range Estimation	4.33	3.75	4.75	.21
Target Acquisition	5.17	5.50	5.38	.93
Kept Bogey in Sight	4.67	4.25	5.13	.69
Weapons Parameters Recognition	4.50	3.25	4.38	.09*
Switchology	3.50	2.88	4.13	.29
Preparation	6.17	6.00	5.00	.29
Attitude	7.00	7.25	7.00	.93
Judgment	6.50	5.13	5.13	.20
Set 1 Maneuvers	4.03	3.73	3.64	.29
Set 2 Skills	5.17	4.79	4.96	.50

*Significant at $p < .10$.

Table D4. **Mean Final Ratings in Aircraft and Significance Probability**

Maneuver/Skill	Group: No-SAAC	No-Motion	Motion	Significance Probability
Acceleration Maneuver	4.83	4.50	4.38	.58
High Yo-Yo	5.17	4.75	4.63	.45
Quarter Plane	5.50	5.00	4.00	.04*
Barrel Roll Attack	4.67	3.88	4.25	.47
Immelmann Attack	4.83	4.13	4.63	.54
Lag Roll	–	–	–	–
Separation	4.67	4.86	4.13	.58
Tactical Formation	4.67	4.75	4.75	.97
Set up on Perch	5.00	5.38	5.43	.45
Defensive Maneuvers	4.67	4.25	4.29	.78
Descriptive Commentary	5.00	4.50	4.83	.90
Range Estimation	4.50	4.63	4.75	.87
Target Acquisition	4.83	5.43	5.00	.66
Kept Bogey in Sight	4.33	4.88	5.13	.61
Weapons Parameters Recognition	4.33	4.43	5.00	.71
Switchology	4.33	4.88	4.88	.80
Preparation	7.02	6 63	5.88	.35
Attitude	6.17	6.63	6.13	.88
Judgment	6.50	4.75	[illegible].00	.15
Set 1 Maneuvers	4.89	4.56	[illegible].47	.06*
Set 2 Skills	5.22	5.24	5.19	.98

*Significant at $p < .10$.

Table D5. **Mean Overall Ratings in Aircraft and Significance Probability**

Maneuver/Skill	Group No-SAAC	No-Motion	Motion	Significance Probability
Acceleration Maneuver	5.01	4.27	4.11	.01*
High Yo-Yo	4.59	4.18	4.46	.46
Quarter Plane	4.27	4.24	3.63	.50
Barrel Roll Attack	4.14	3.97	3.66	.57
Immelmann Attack	4.21	3.97	3.73	.66
Lag Roll	4.29	3.77	3.91	.78
Separation	4.64	4.34	3.73	.33
Tactical Formation	4.31	4.14	4.79	.11
Set up on Perch	4.56	4.77	4.65	.89
Defensive Maneuvers	4.45	4.27	4.67	.55
Descriptive Commentary	4.76	4.76	4.11	.26
Range Estimation	4.33	4.54	4.63	.74
Target Acquisition	4.60	5.33	5.33	.21
Kept Bogey in Sight	4.24	4.99	5.03	.37
Weapons Parameters Recognition	4.38	3.91	4.71	.19
Switchology	4.13	4.22	4.30	.93
Preparation	6.26	6.12	5.56	.45
Attitude	6.71	6.91	7.00	.90
Judgment	5.44	5.35	5.38	.99
Set 1 Maneuvers	4.44	4.20	4.13	.12
Set 2 Skills	4.98	5.12	5.12	.79

*Significant at $p < .10$.

Table D6. **Significance Probabilities of Initial vs Final Data**

Maneuver/Skill	Simulator No-Motion	Simulator Motion	Aircraft No-SAAC	Aircraft No-Motion	Aircraft Motion
Acceleration Maneuver	.18	.05*	.72	.42	.54
High Yo-Yo	.86	.07*	.18	.01*	.26
Quarter Plane	.06*	.01*	.03*	.01*	.15
Barrel Roll Attack	.28	.01*	.21	.88	.03*
Immelmann Attack	.10*	.03*	.14	.12	.02*
Lag Roll	+	+	+	+	+
Separation	.37	.39	.20	.44	.27
Tactical Formation	.04*	.12	.41	.06*	.06*
Set up on Perch	1.00	.45	.26	.35	.05*
Defensive Maneuvers	.13	.10*	.77	1.00	.38
Descriptive Commentary	.03*	.01*	.67	.59	.07*
Range Estimation	.13	.06*	.79	.12	1.00
Target Acquisition	.46	.34	.69	.93	.56
Kept Bogey in Sight	+	+	.74	.56	1.00
Weapons Parameters Recognition	.14	.28	.77	.20	.39
Switchology	.29	.35	.34	.02*	.41
Preparation	.90	.57	.36	.39	.27
Attitude	.71	.66	.38	.40	.26
Judgment	.18	.47	1.00	.64	.88
Set 1 Maneuvers	.01*	.01*	.01*	.01*	.01*
Set 2 Skills	.83	.01*	.48	.16	.37

*Significant at $p < .10$.
+Insufficient data.

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